Bridging the Gap
Between Subseasonal and Seasonal Forecasts and Decisions to Act

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Jeremy D. Ross

NMME Sub-Seasonal Forecast System
Exploratory Workshop

NCWCP Conference Center, College Park Md
30-31 March 2015

Expanded from an Earlier Version:
AMS 95th Meeting, Phoenix, 7 January 2015

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If you knew then what we knew then ...

Topics for Today

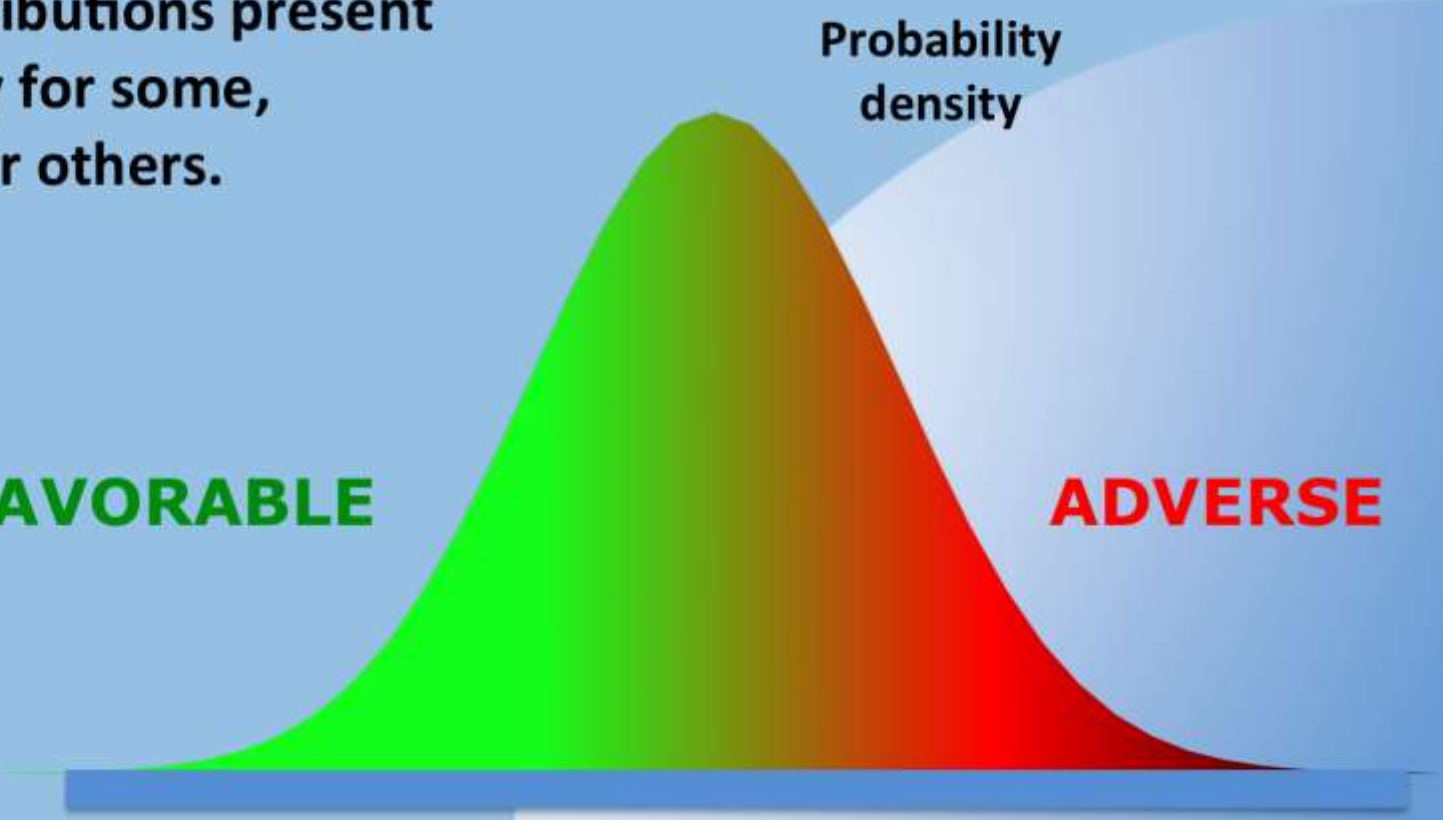
- **World Climate Service Seasonal Forecasts**
  with an emphasis on skill
- **World Climate Service Subseasonal Forecasts**
  with an emphasis on skill
- **Mitigating Predicted Adverse Events**
  with a focus on the consequences of
  hedging on forecast
- **Implications for S2S Forecast Systems**
- **Implications for NMME**

Theme for Today

The *value* of weather and climate forecasts lies in the *action* they motivate and the favorable *consequences* that follow.

Adversity and Opportunity

Subseasonal and seasonal climate variations in the tails of distributions present opportunity for some, adversity for others.



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A Client's Plea

Don't tell me about the weather

Tell me about the money


First, the ‘weather’…

Prescient Weather

MeteoGroup

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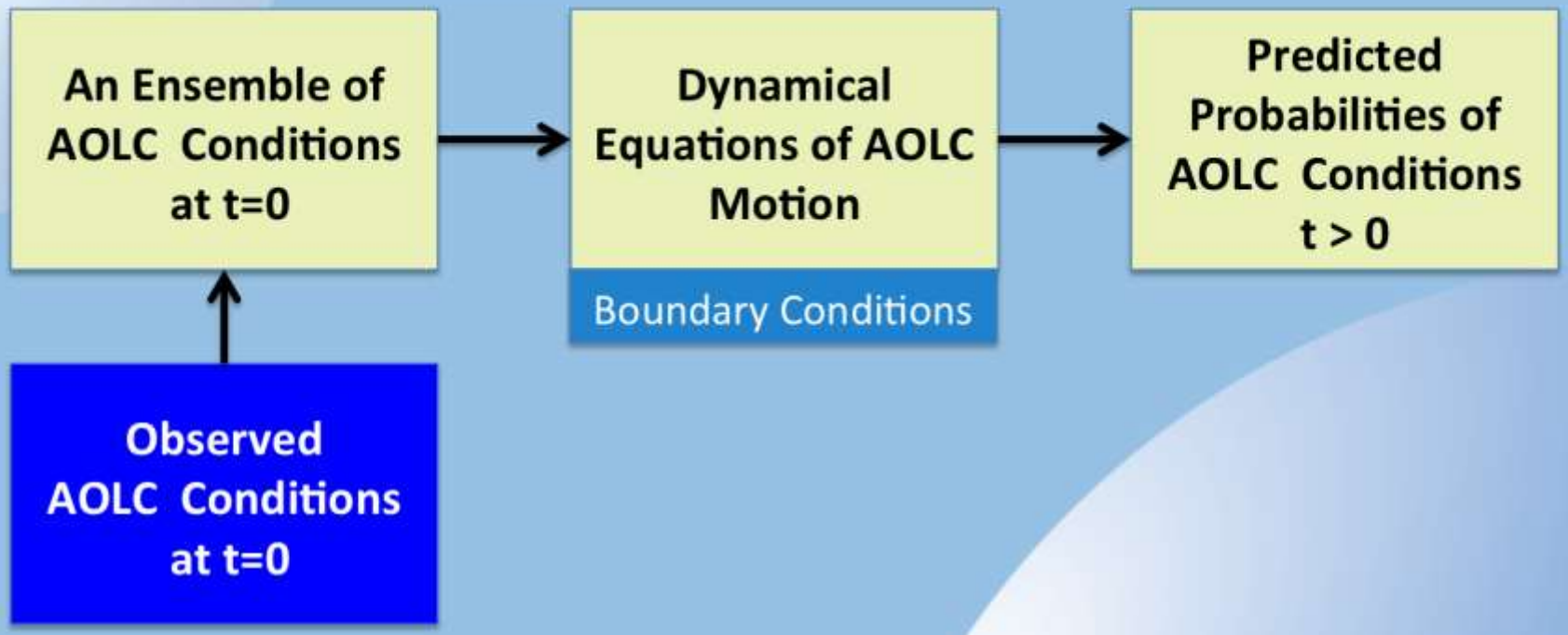
www.worldclimateservice.com

Dynamical Forecasts



Atmosphere
Ocean
Land
Cryosphere

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Dynamical Forecasts

An Ensemble of AOLC Conditions at t=0

→

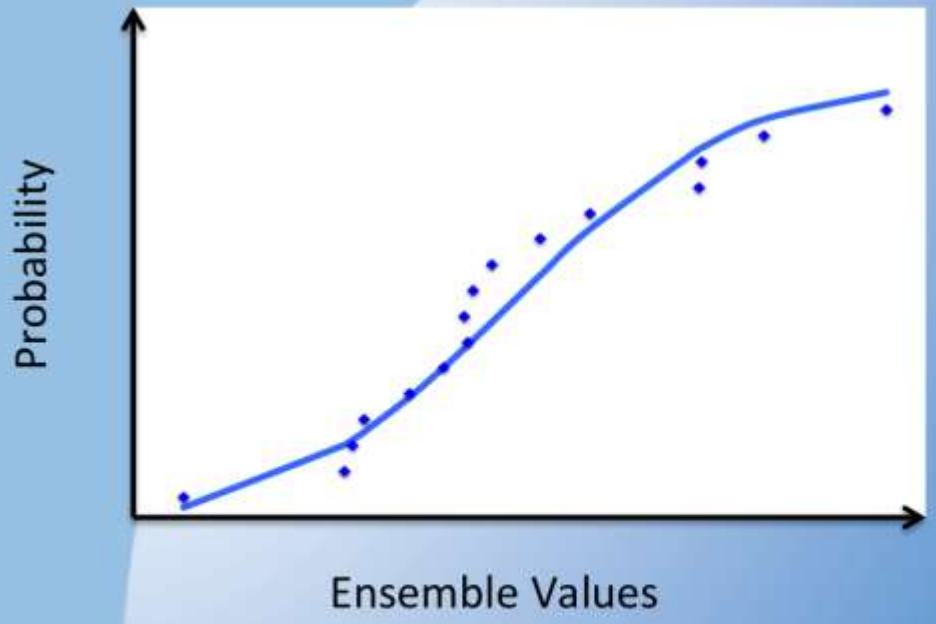
Dynamical Equations of AOLC Motion

Boundary Conditions

→

Predicted Probabilities of AOLC Conditions t > 0

Observed AOLC Conditions at t=0



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If you knew then what we knew then ...

Home | Forecasts | Climate Analysis Tools | Free Climate Tools | About WCS | Contact

Region selection

full globe

Model selection

Model	ECMWF	CFSv2	Multi-model
Variable	Temp	Precip	MSLP
Forecast	Probability	Anomaly	

Climatology selection (note)

1982-2009 | 2000-2009

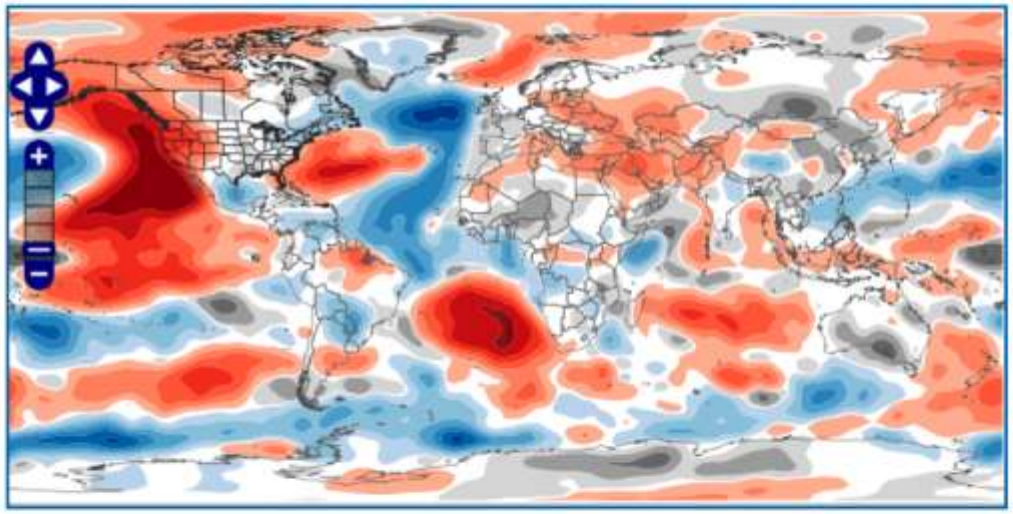
Month selection

Forecast for →

Reset

Forecast made ↓	FEB 2015	MAR 2015	APR 2015	MAY 2015	JUN 2015	JUL 2015
MAR 2015						
FEB 2015						
JAN 2015						
DEC 2014						
NOV 2014						
OCT 2014						

Multi-model Temperature Probability
2000-2009 Climatology
Forecast made January 2015 for February 2015



90 80 70 60 50 40 40 50 60 70 80 90 90 80 70 60 50 40 40 50 60 70 80 90

Below | Normal | Above

Download as: PDF | GeoTiff | KMZ

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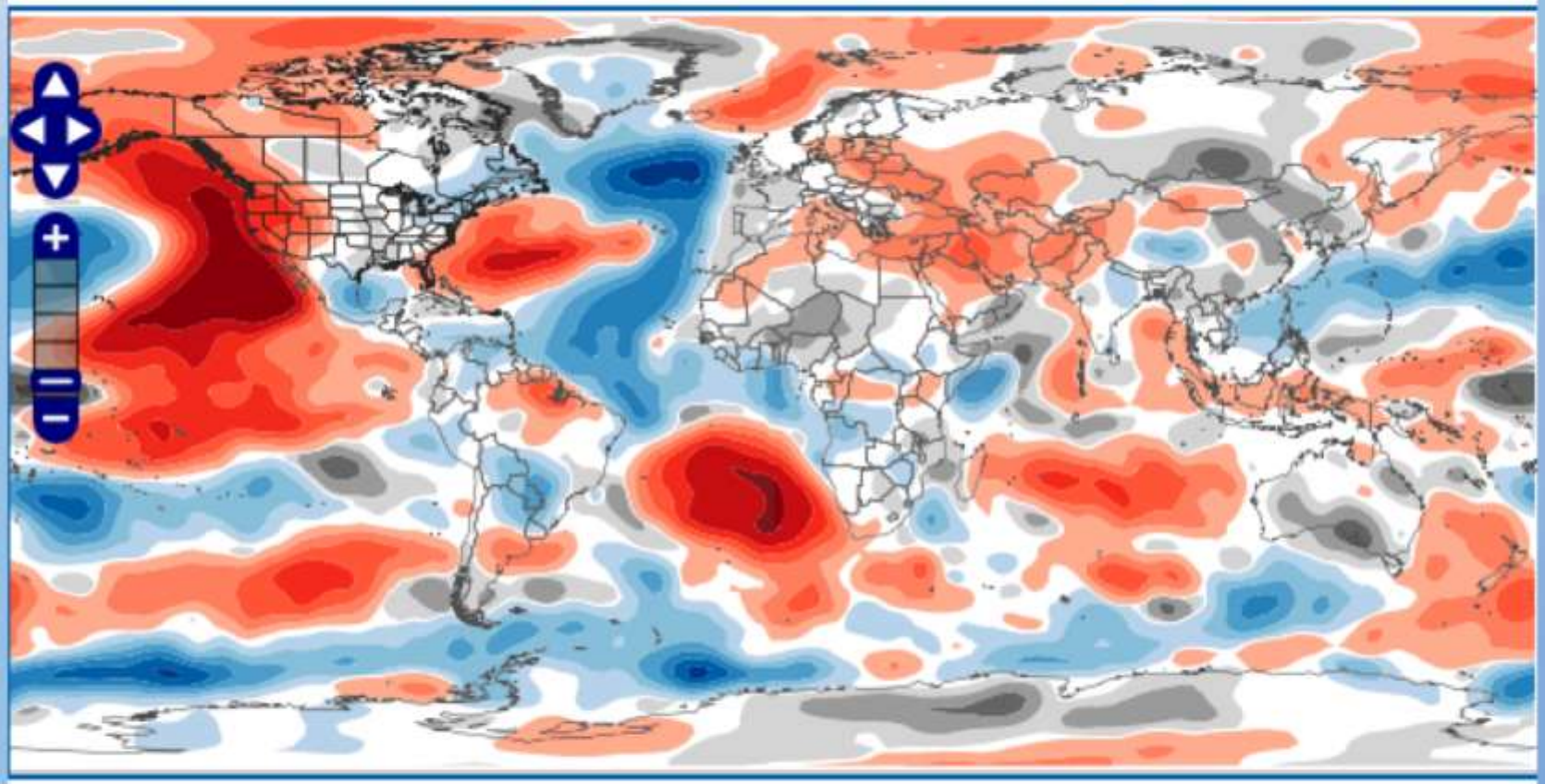
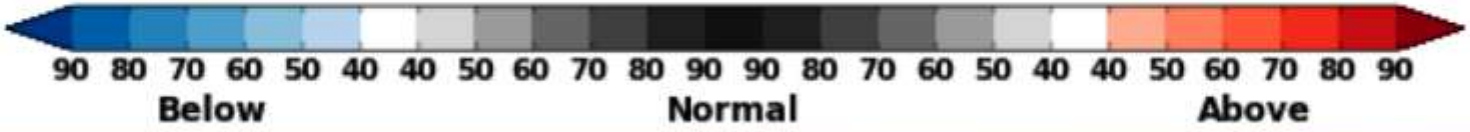
Multi-model Temperature Probability
2000-2009 Climatology
Forecast made January 2015 for February 2015





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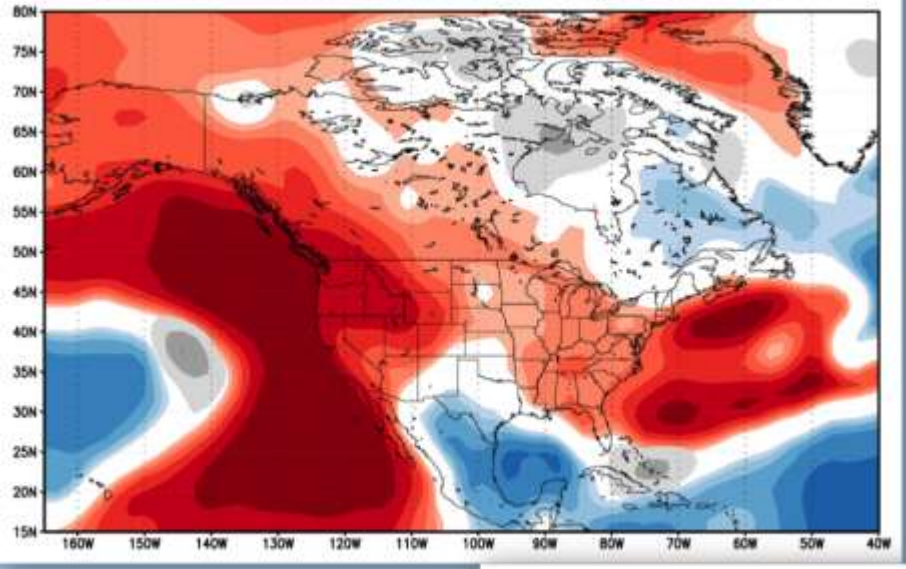
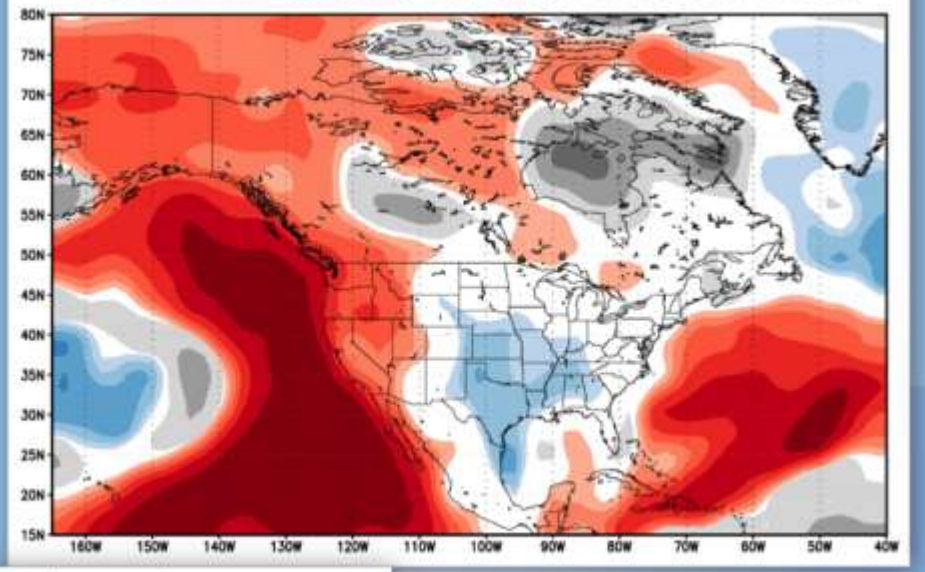
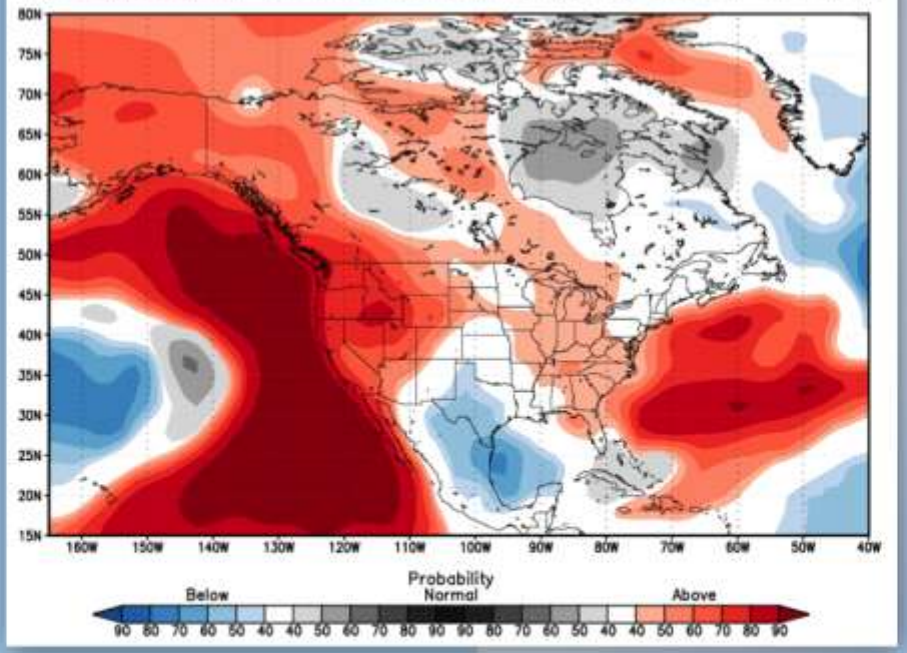
CFSv2 T2m Probability Above/Normal/Below FMA 2015



ECMWFv4 T2m Probability Above/Normal/Below FMA 2015



WCS Multi-Model T2m Probability Above/Normal/Below FMA 2015



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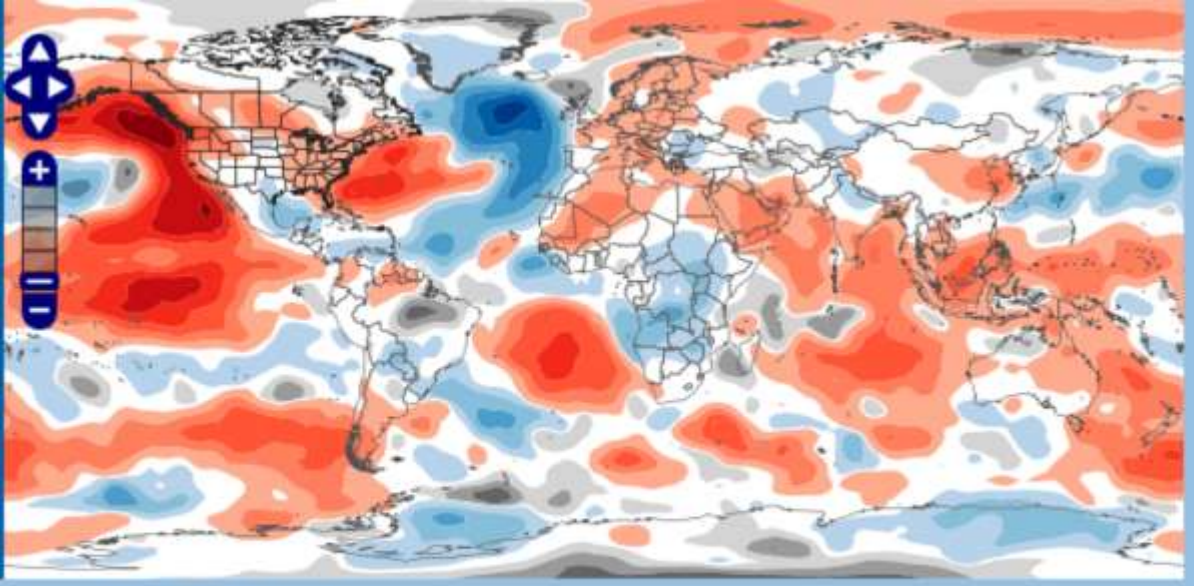
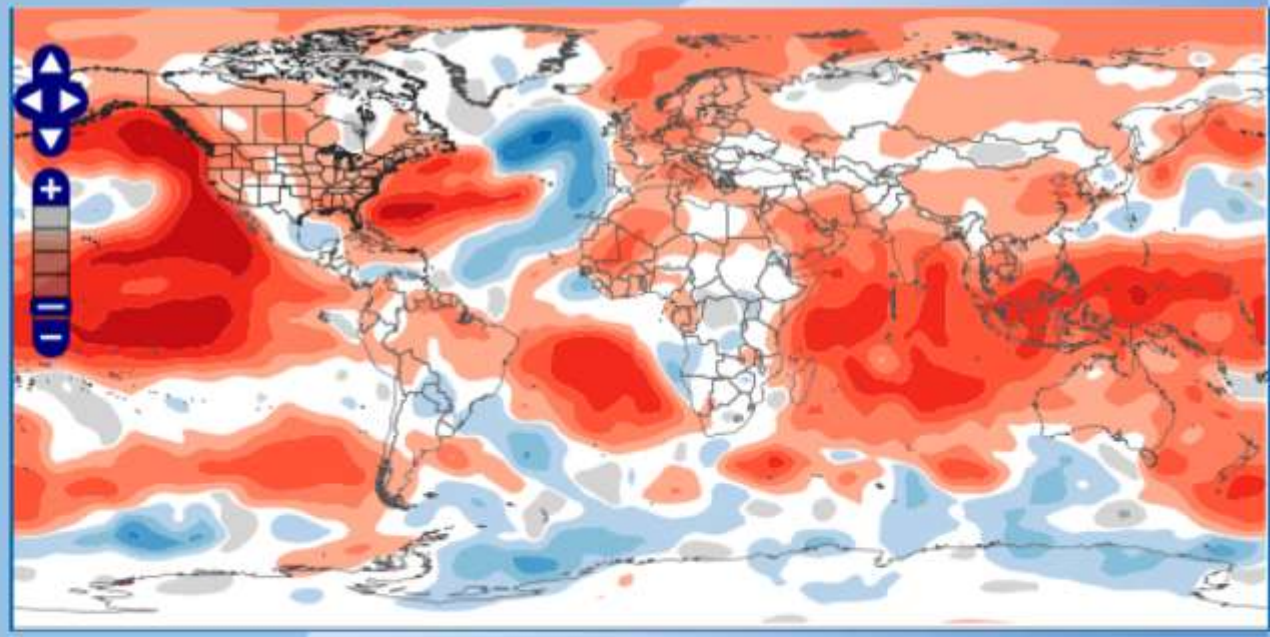


WCS MME
Temperature
Jan 15 -> Apr 15

2000-2009
Climatology



1982-2009
Climatology

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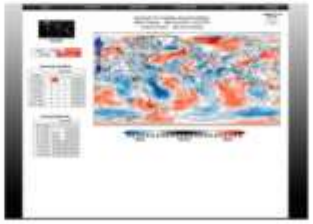
World Climate Service subseasonal forecasts

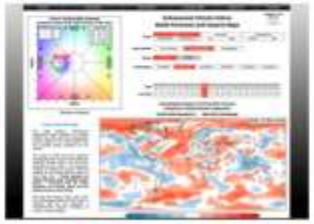
Subseasonal forecast information from the World Climate Service allows you to:

- **Manage risk and opportunity** related to subseasonal weather and climate variability
- **Gauge forecast signals and confidence** for potential outcomes with 2-6 weeks of advance warning
- **Develop profitable strategies** for business or financial decisions using known forecast skill

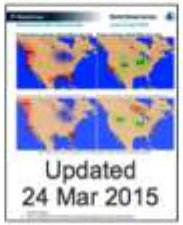
Model Forecasts



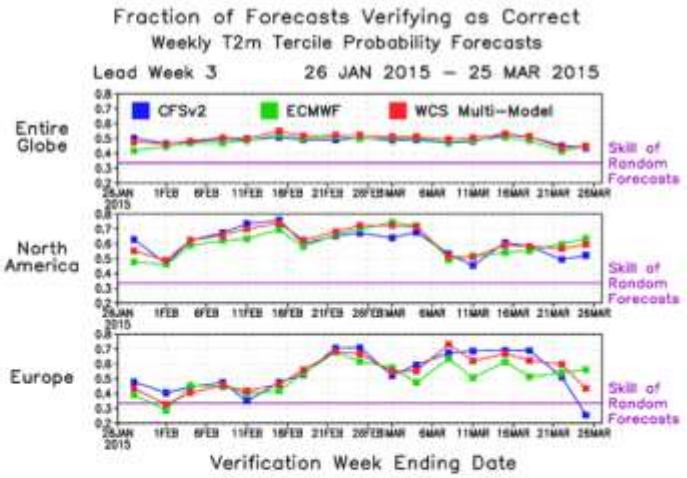
Climate Index Forecasts and Tools



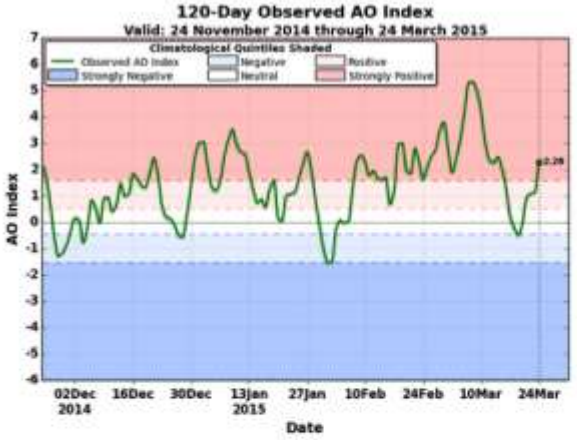
Latest U.S. Forecast Summary



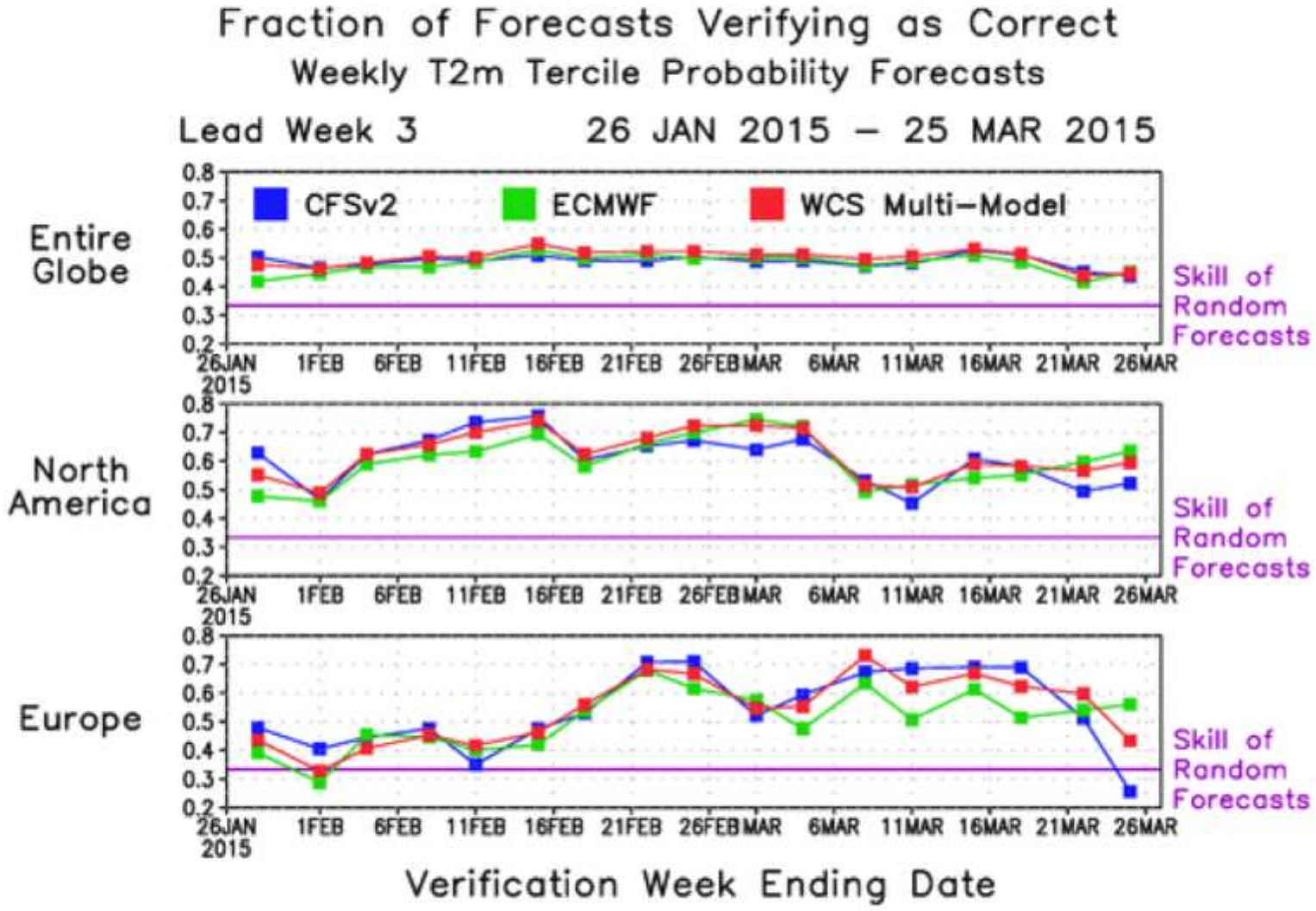
Skill of Recent Dynamical Model Temperature Forecasts



Climate Index Observations and Impacts



Skill of Recent Dynamical Model Temperature Forecasts



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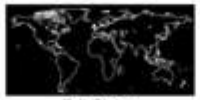

Full Globe

Forecast Model

CFSv2	ECMWF	Multi-Model

Forecast Variable

T2m	Precip	MSLP	Wind
Anomaly		Probability	

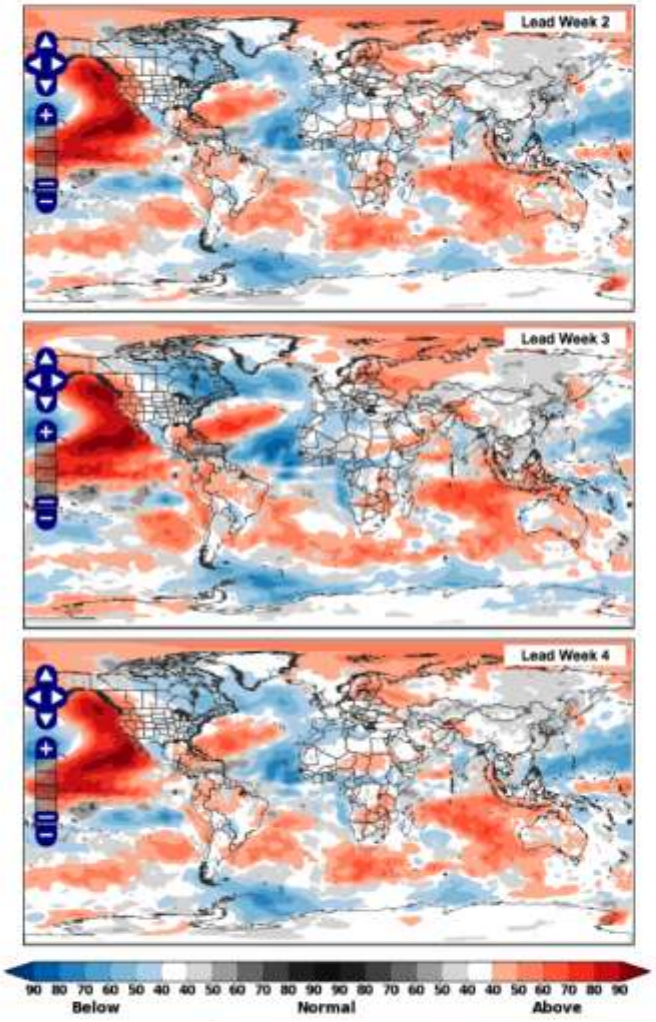
Forecast by Lead Week

	Lead Week					
Init date	1	2	3	4	5	6
23 Mar 2015						
16 Mar 2015						
9 Mar 2015						
2 Mar 2015						

Forecast Progression

	Lead Weeks			
Week Ending	1-3	2-4	3-5	4-6
29 Mar 2015				
5 Apr 2015				

Multi-Model T2m Probability Above/Normal/Below
Weekly Forecasts Valid 30 Mar 2015 - 5 Apr 2015
Lead Weeks 2(top) 3(middle) 4(bottom) 2001-2010 Climatology



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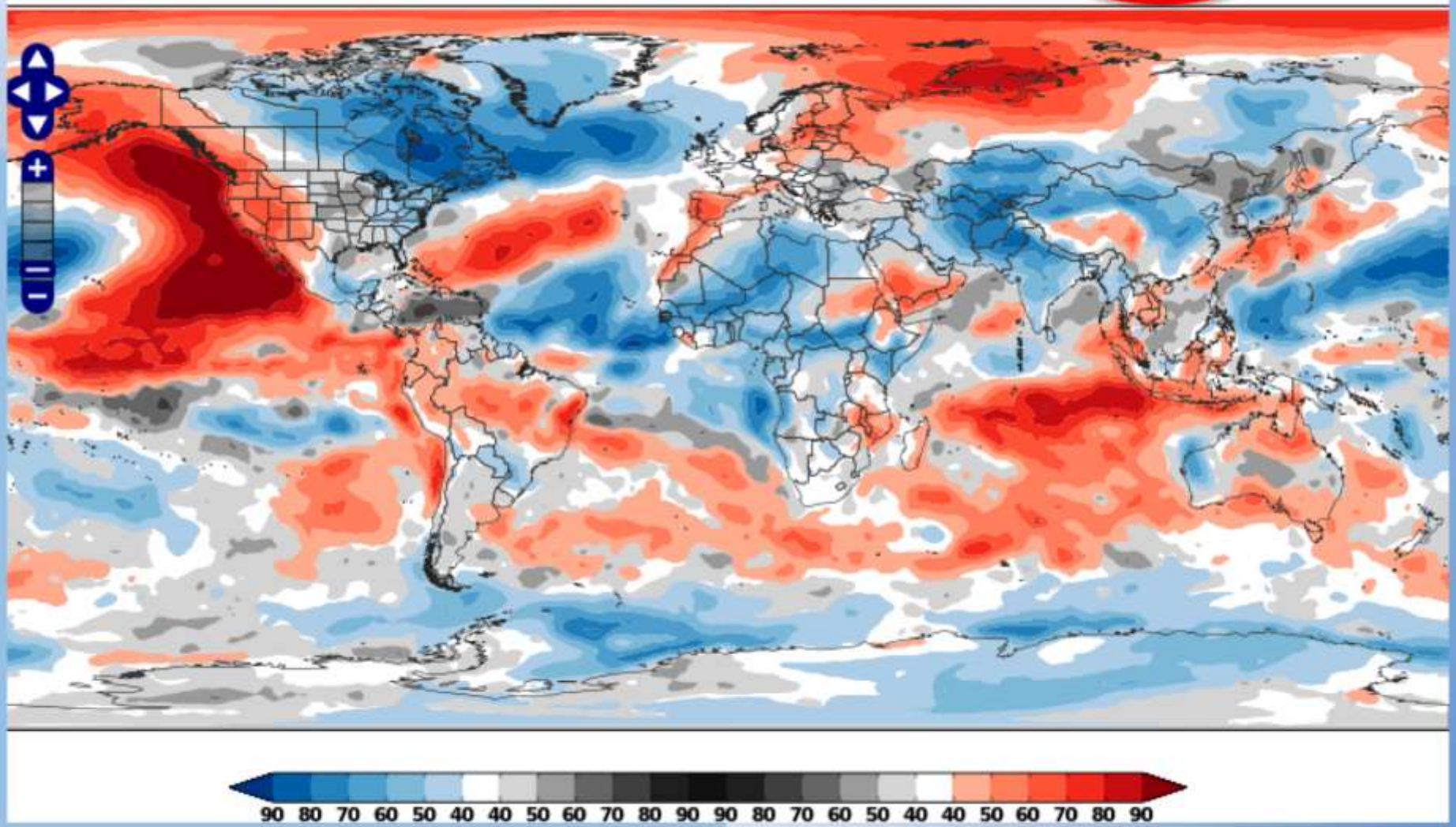
Multi-Model T2m Probability Above/Normal/Below

Week 2 Forecast Valid 30 Mar 2015 - 5 Apr 2015

Initialized 23Mar2015 2001-2010 Climatology

Toggle skill map



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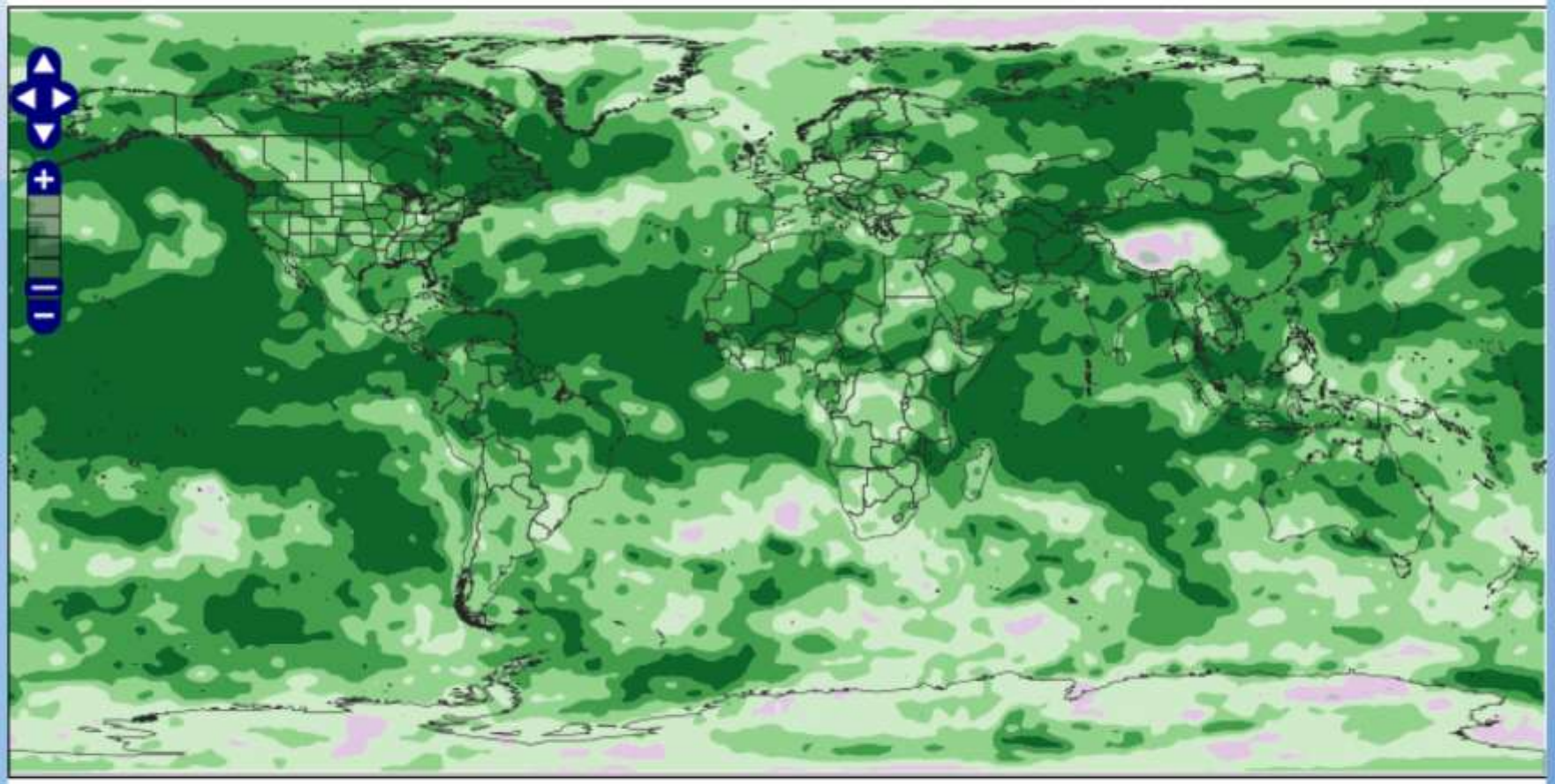
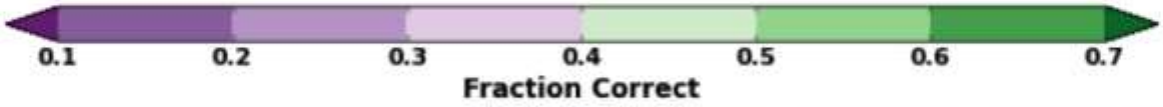
Multi-Model T2m Tercile Fraction Correct at Current Forecast Confidence

Week 2 Forecast Valid 30 Mar 2015 - 5 Apr 2015

Initialized 23Mar2015 2001-2010 Climatology

☑ Toggle skill map





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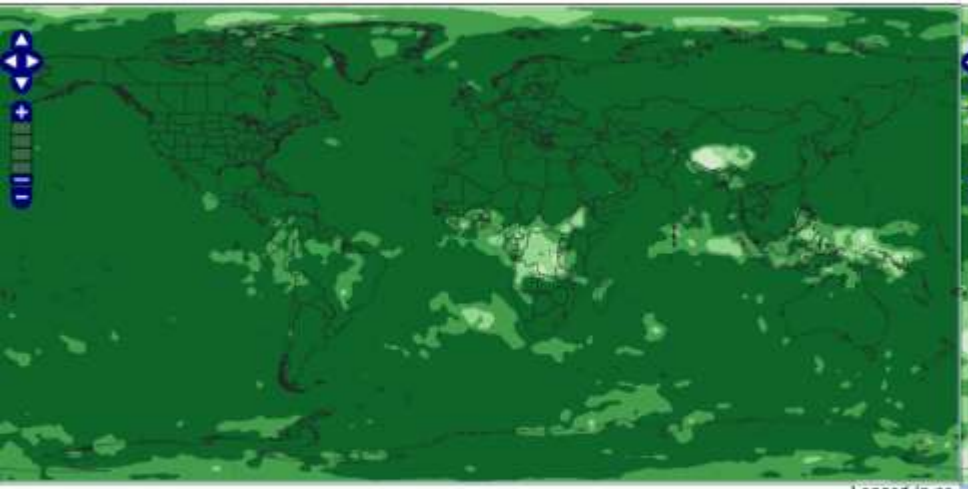
Multi-Model T2m Tercile Fraction Correct at Current Forecast Confidence

Week 1 Forecast Valid 23 Mar 2015 - 29 Mar 2015

Initialized 23Mar2015 2001-2010 Climatology

Toggle skill map



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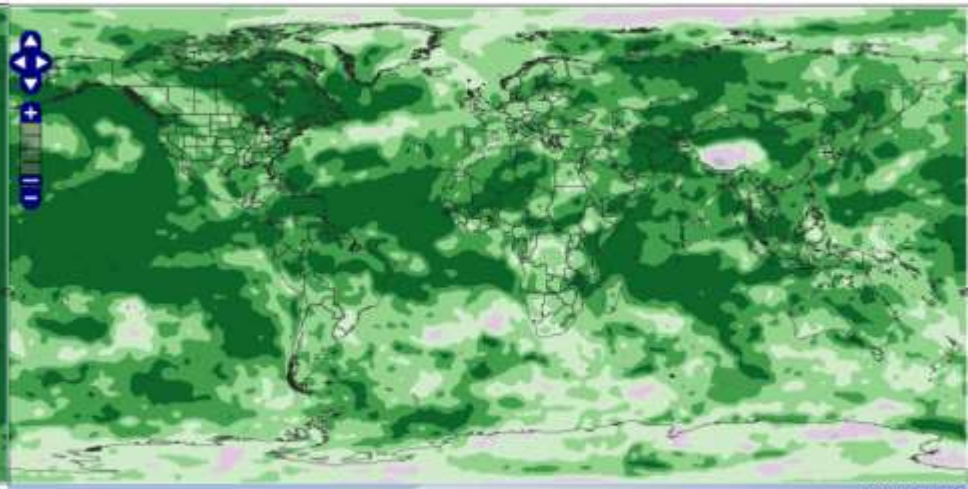
Multi-Model T2m Tercile Fraction Correct at Current Forecast Confidence

Week 2 Forecast Valid 30 Mar 2015 - 5 Apr 2015

Initialized 23Mar2015 2001-2010 Climatology

Toggle skill map



Logged in as

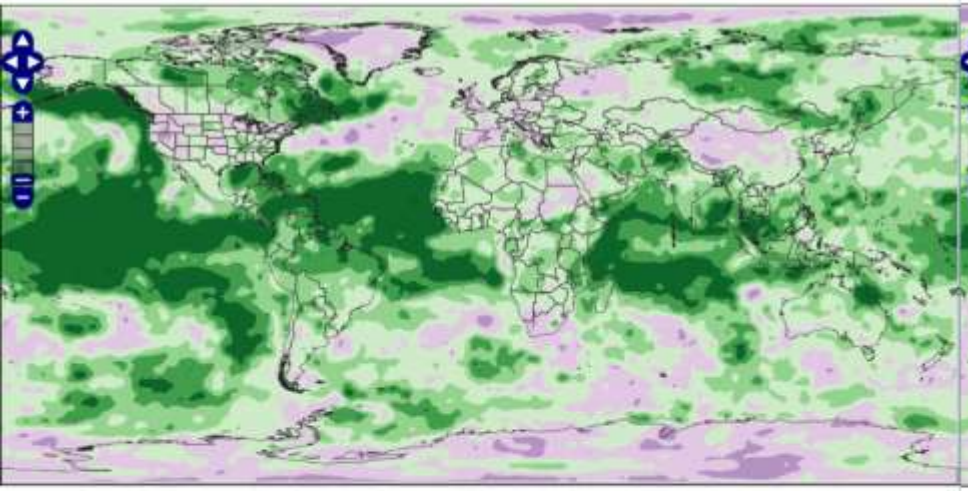
Logout

Multi-Model T2m Tercile Fraction Correct at Current Forecast Confidence

Week 3 Forecast Valid 6 Apr 2015 - 12 Apr 2015

Initialized 23Mar2015 2001-2010 Climatology

Toggle skill map



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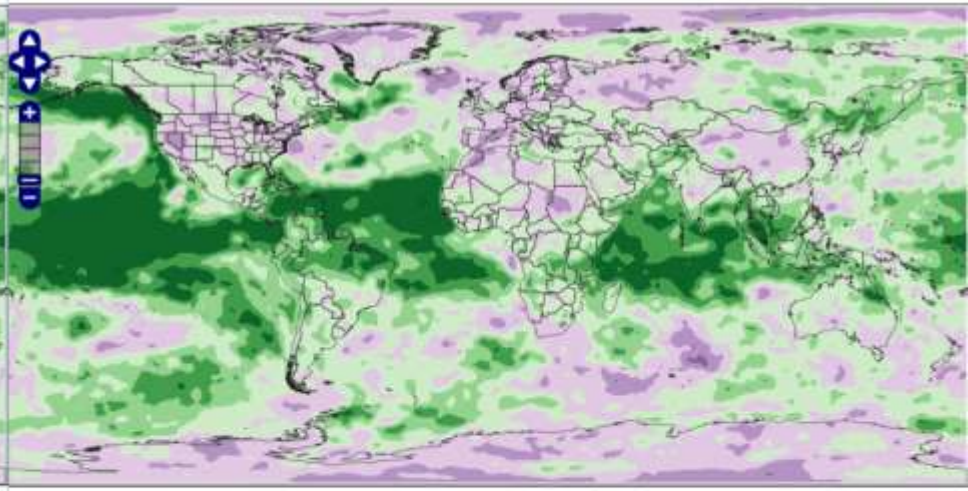
Multi-Model T2m Tercile Fraction Correct at Current Forecast Confidence

Week 4 Forecast Valid 13 Apr 2015 - 19 Apr 2015

Initialized 23Mar2015 2001-2010 Climatology

Toggle skill map



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Financial information on assets, the financial statements and results of the Company

Consolidated income statements

(in millions of Euros)	Notes	2014	2013 (1)
Sales	7	72,874	71,916
Fuel and energy purchases	8	(36,704)	(38,116)
Other external expenses	9	(9,181)	(8,287)
Personnel expenses	10	(11,785)	(11,291)
Taxes other than income taxes	11	(3,593)	(3,481)
Other operating income and expenses	12	5,668	5,358
Operating profit before depreciation and amortisation		**17,279**	**16,099**
Net changes in fair value on Energy and Commodity derivatives, excluding trading activities		203	14
Net depreciation and amortisation		(7,940)	(7,154)
Net increases in provisions for renewal of property, plant and equipment operated under concessions		(157)	(227)
(Impairment) / reversals	13	(1,189)	(617)
Other income and expenses	14	(212)	219
Operating profit		**7,984**	**8,334**
	15.1	(2,243)	(2,262)
	15.2	(2,996)	(2,931)
	15.3	2,688	2,251
	15	**(2,551)**	**(2,942)**
Income before taxes of consolidated companies		**5,433**	**5,392**
Income taxes	16	(1,839)	(1,896)
Share in net income of associates and joint ventures	23	179	262
GROUP NET INCOME		3,773	3,758
EDF net income		**3,701**	**3,517**
Net income attributable to non-controlling interests		**72**	**241**
Earnings per share (EDF share) in Euros:	17		
Earnings per share		**1.78**	**1.84**
Diluted earnings per share		**1.78**	**1.84**

(1) Figures for 2013 have been restated for the impact of retrospective application of IFRS 10 and IFRS 11 (see note 2).

...and now the money...10^6 €...

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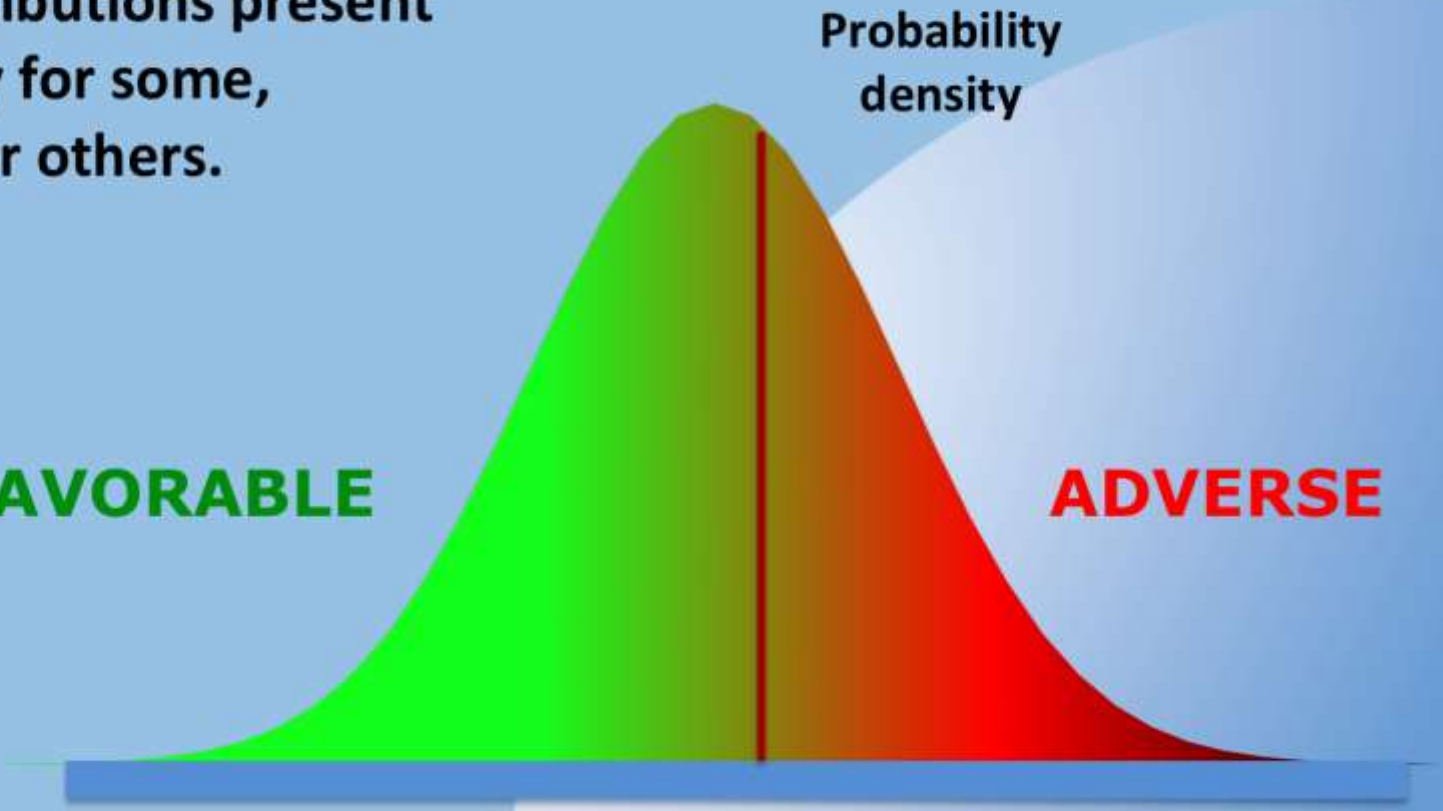
Adversity and Opportunity

Subseasonal and seasonal climate variations in the tails of distributions present opportunity for some, adversity for others.



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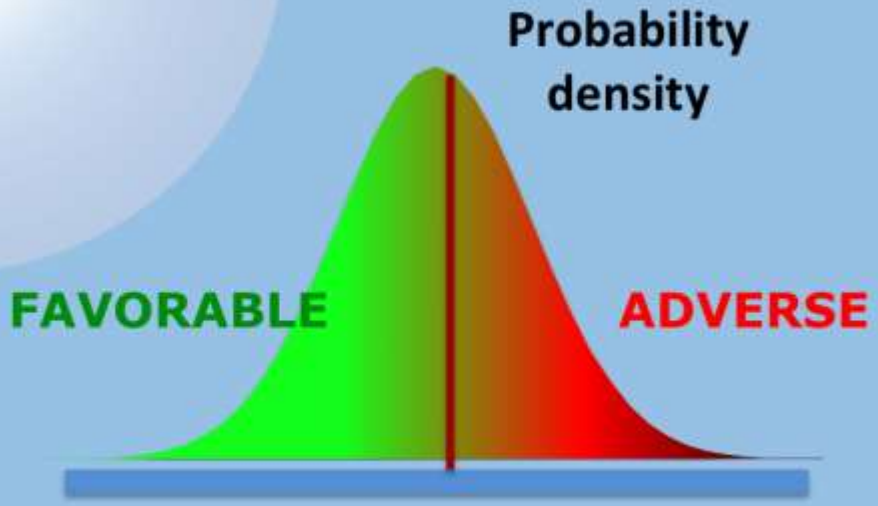

Adverse Financial Results

- Loss of Revenue
- Volatility of Earnings

Goals of Mitigation Strategies

- Decrease Loss of Revenue
- Decrease Volatility of Earnings

With Hedges or Other Maneuvers

There is always someone who will absorb your risk for some price.

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Choices to Make

When adverse weather or climate variations are predicted, we can choose to

- Accept the consequences
- Attempt to mitigate them

The critical question:

How do the consequences expected with mitigation compare to those expected without mitigation?

When to Act

Users of the forecasts ask:

**At what predicted probability *p*
of adverse conditions should I act?**

A better and more comprehensive question:

**What *consequences* can I expect if I act
at a predicted probabilities $\geq p$ of adverse conditions?**

***expect* => E[ ]**

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Expected Consequences

To provide the estimates E[consequences | *p*], we need

- A model of the business or activity
  that permits quantitative assessment
- A description of adversity relative to the model
- A detailed description of the performance
  of the forecast system relative to predicted probabilities, *p*
- A method for estimating the cost of mitigation

Contingency Table: Forecasts and Events

		Events	
		Adverse	Favorable
Forecasts	Adverse		
	Favorable		

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Business Model – Accept Climate Variations

		Events	
		Adverse	**Favorable**
Fore-casts	**Adverse**	$R_f - L$	R_f
	Favor -able	$R_f - L$	R_f

$$L = R_f - R_a$$

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Business Model – Hedge on Forecast

		Events	
		Adverse	**Favorable**
Fore-casts	**Adverse**	$R_f - L + H - C(H)$	$R_f - C(H)$
	Favor -able	$R_f - L$	R_f

$$L = R_f - R_a$$

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Forecast Statistics for the Binary Model of Events—Functions of *p*

		Events		
		Adverse	Favorable	Sum
Fore-casts	Adverse	$f_a F_a$	$f_a(1-F_a)$	f_a
	Favorable	$n_a - f_a F_a$	$1-n_a-f_a(1-F_a)$	$1-f_a$
	Sum	n_a	$1-n_a$	*1*

n_a	climatological frequency of adverse events
$f_a = f_a(p)$	fraction of adverse forecasts
$F_a = F_a(p)$	fraction of correct adverse forecasts

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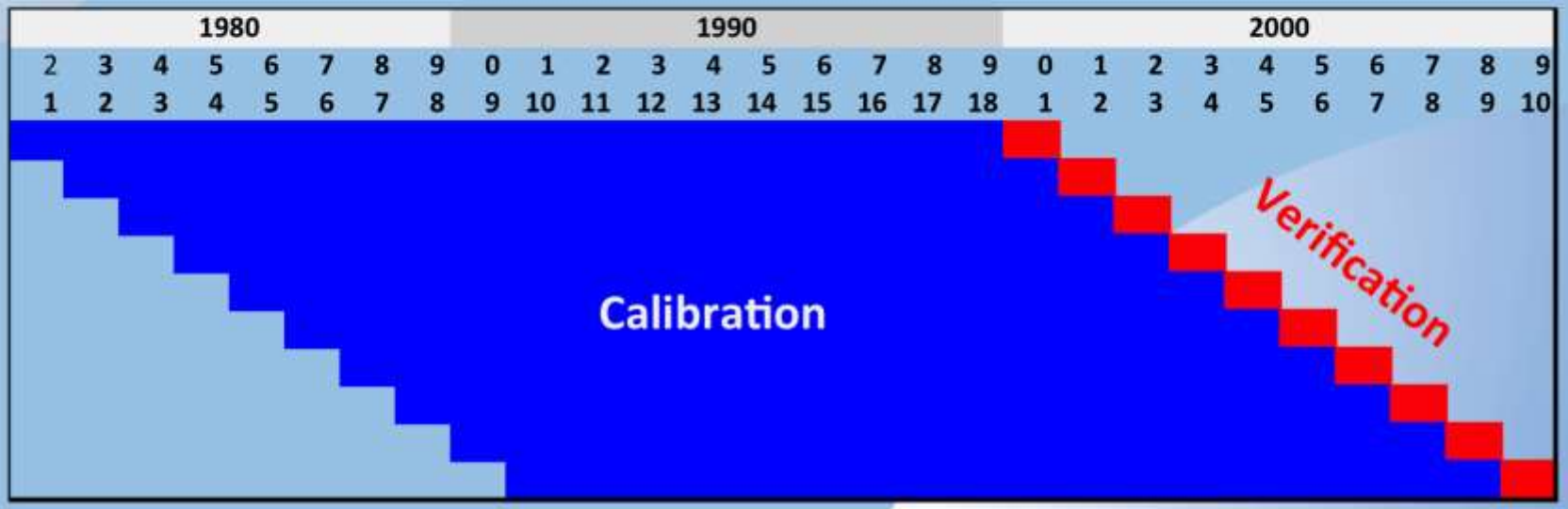
Seasonal Forecast Calibration and Verification



All calibration and verification results here are for temperature (t2m)

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Forecast Performance Statistics

$v(p)$ fraction of correct forecasts in a bin at *p*

$n(p)$ fraction of incorrect forecasts in a bin at *p*

$s(p) = v(p) + n(p)$ sharpness

$f(p) = \int_p^1 s(x)dx$ fraction adverse fcsts prob > p

$F(p) = \int_p^1 v(x)dx \,/\, f(p)$ fraction correct …

$r(p) = v(p) \,/\, s(p)$ reliability function

$$f(p) = \int_p^1 s(x)dx$$

$$F(p) = \int_p^1 r(x)\, s(x)dx \,/\, f(p)$$

→ Expressions with Beta probability distributions defined on [0,1]

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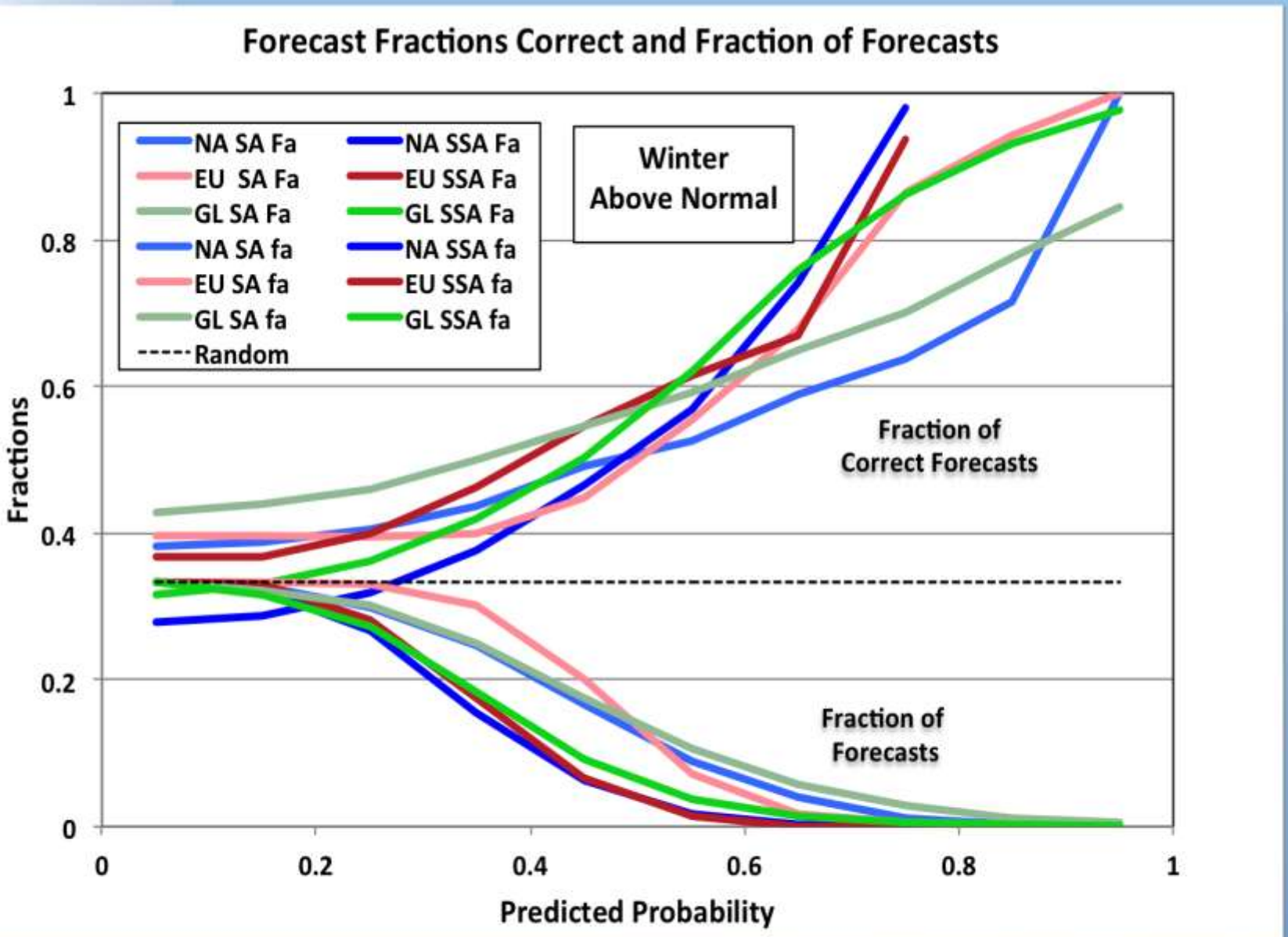

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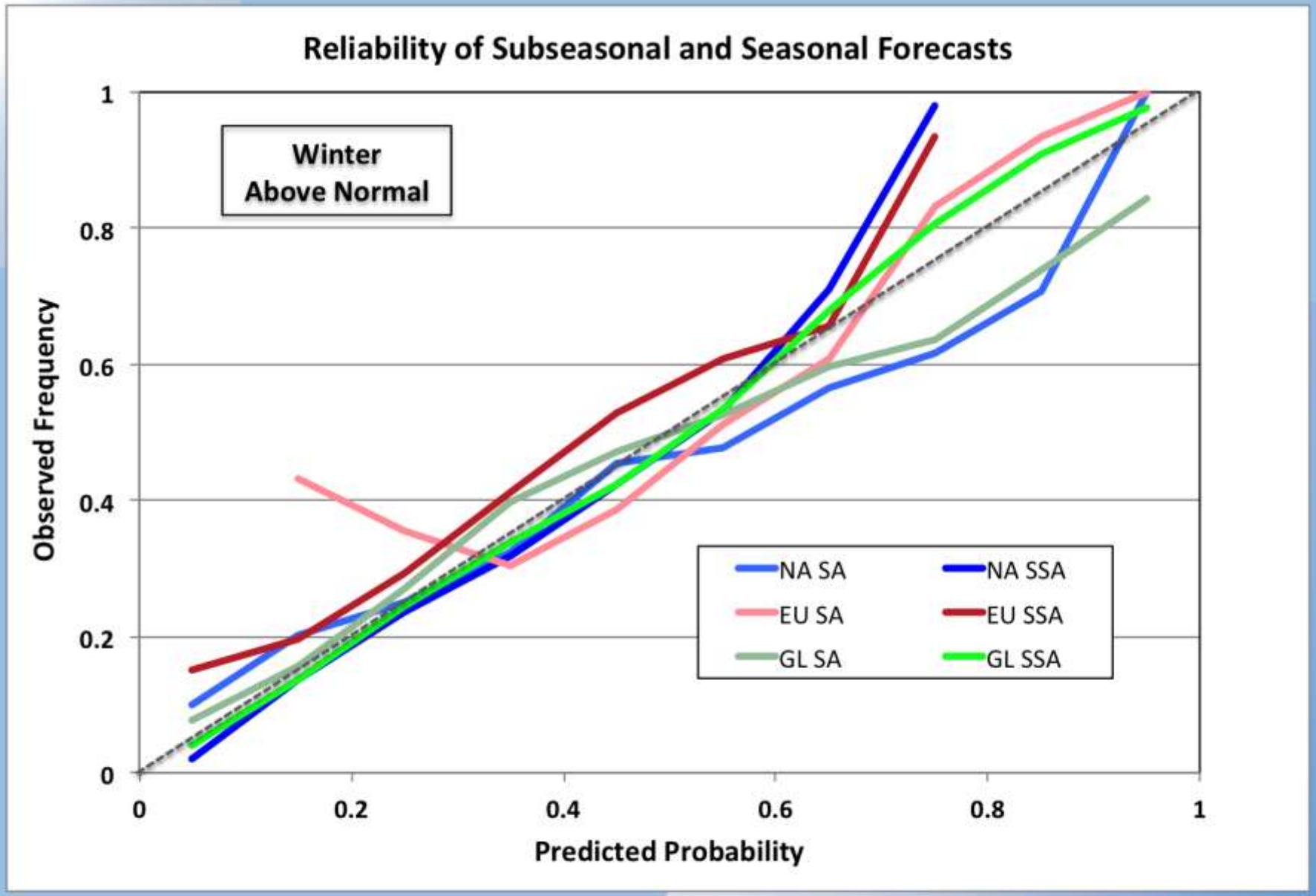

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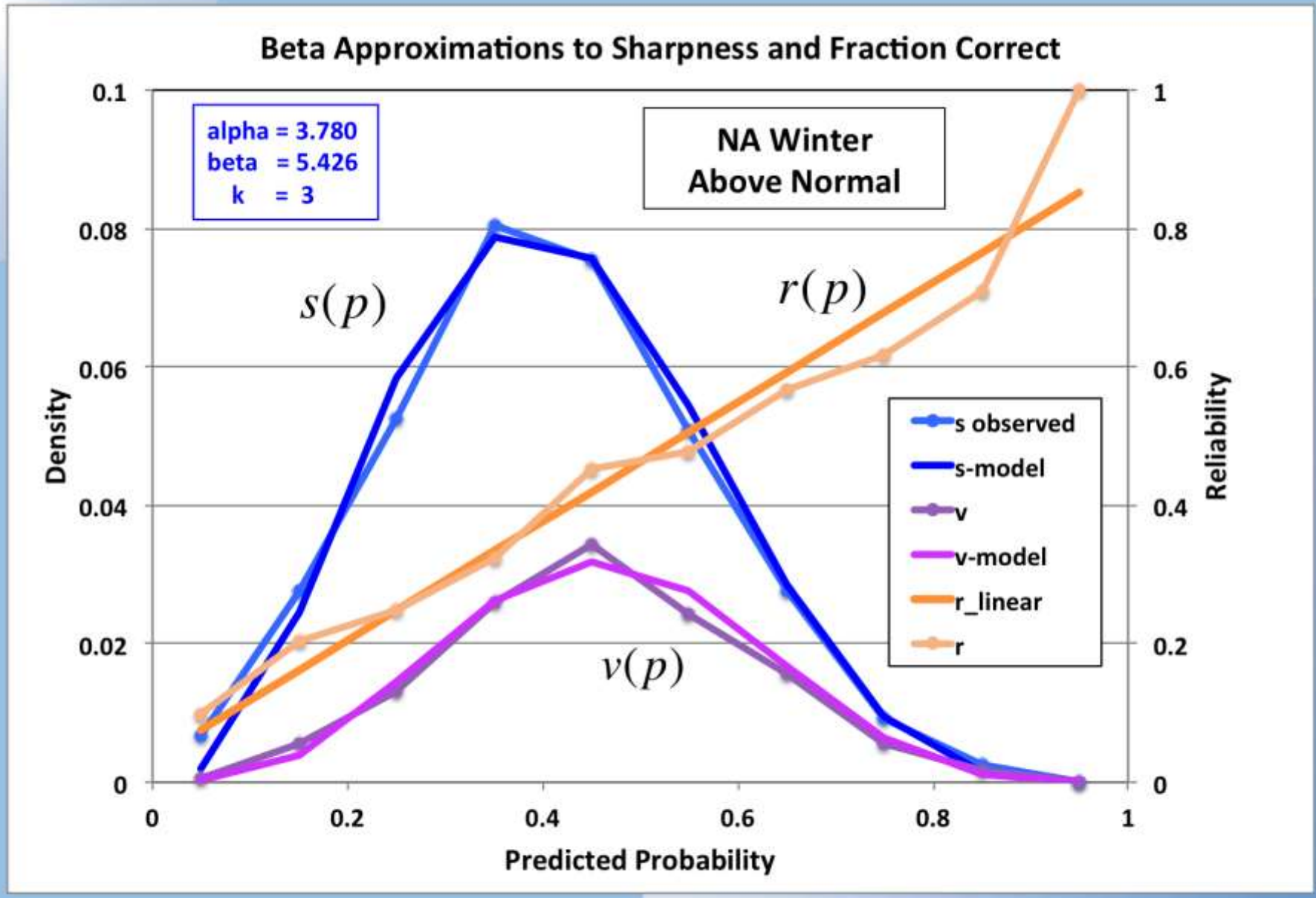

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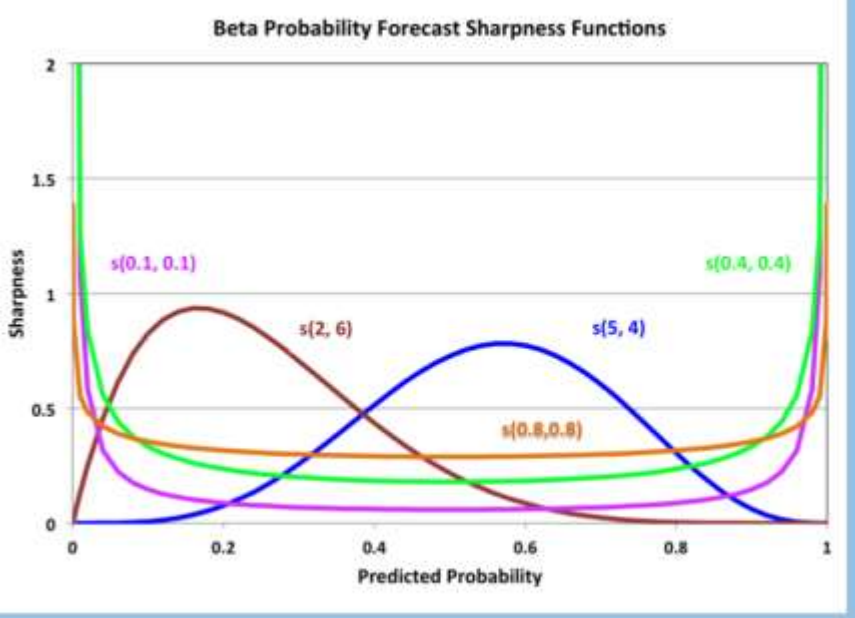

Skill Functions

$$s(p,\alpha,\beta,n_a) = n_a \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} p^{\alpha-1}(1-p)^{\beta-1}$$

$$B(p,\alpha,\beta,n_a) = n_a \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \int_0^p x^{\alpha-1}(1-x)^{\beta-1}\,dx$$

$$r(p) = a + b\,p$$

$$f(p,\alpha,\beta,k) = \int_p^1 s(x,\alpha,\beta,k)\,dx = k\,(1 - B(p,\alpha,\beta))$$

$$F(p,\alpha,\beta,k) = \frac{\int_p^1 v(x,\alpha,\beta,k)\,dx}{f(p,\alpha,\beta,k} = a + b\,\frac{\alpha}{\alpha+\beta}\,\frac{(1 - B(p,\alpha+1,\beta))}{(1 - B(p,\alpha,\beta))}$$

$$\alpha,\ \beta,\ a, b \ \ldots$$

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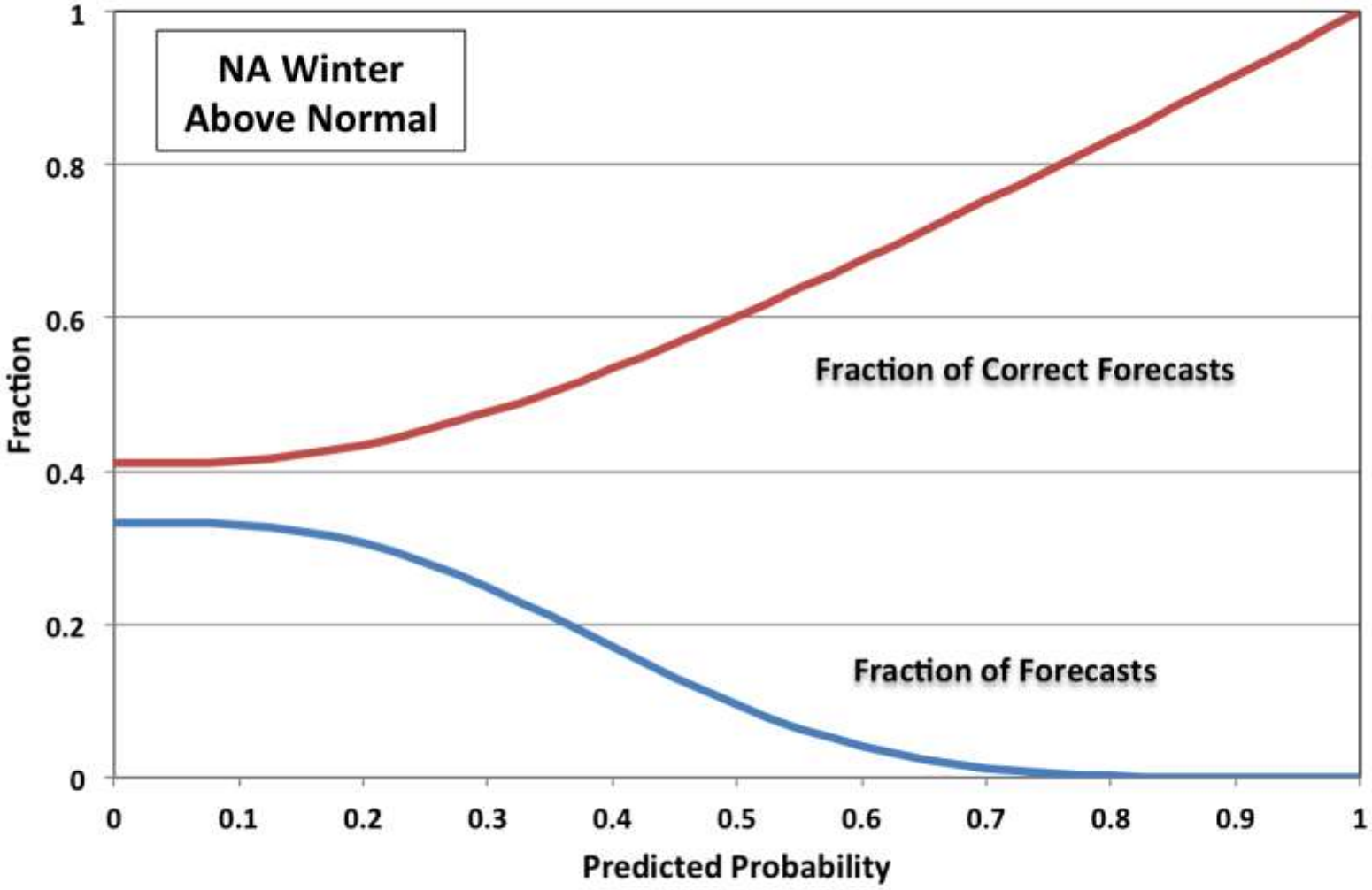
Skill Functions for the North American Winter Seasonal Forecasts



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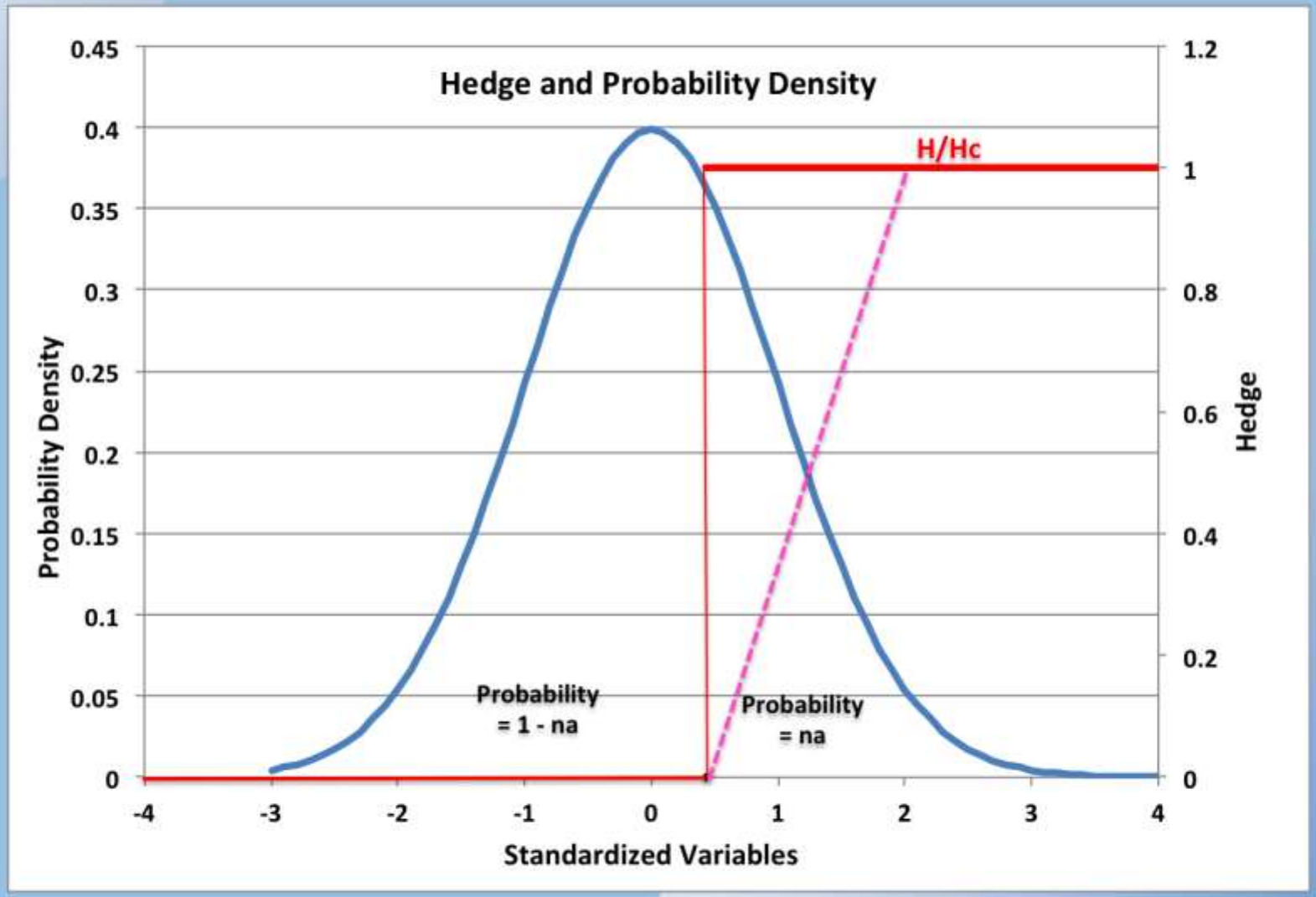
If you knew then what we knew then ...

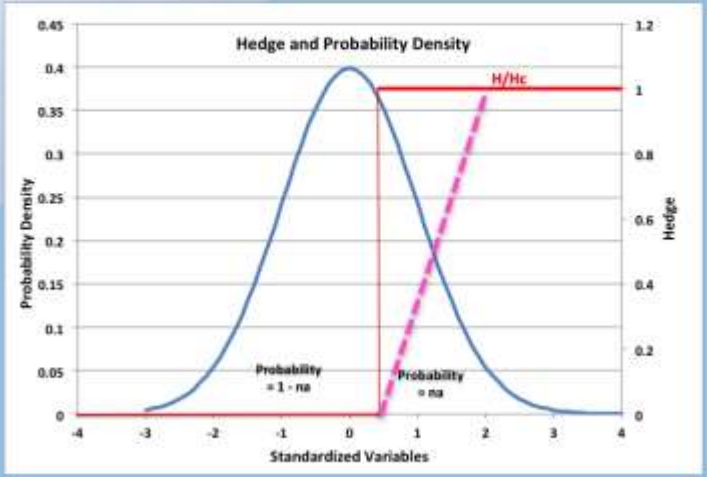
Specification of a Hedge Against Loss



World Climate Service

If you knew then what we knew then ...

Cost of a Hedge



Cost = Expected Payout + Volatility Allowance

$$C(H) = \bar{H} + \kappa\sigma_H$$

For the "box" hedge with payout *H*

$$\bar{H} = n_a H$$

$$\sigma_H{}^2 = n_a(1-n_a)H^2$$

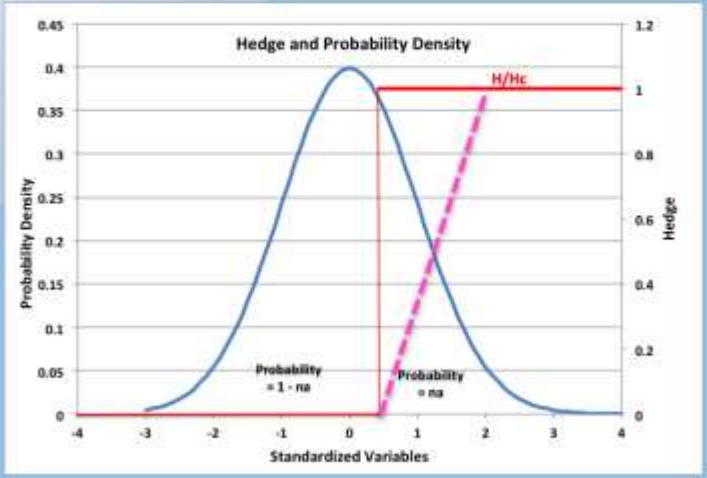
$$C(H) = n_a H + \kappa H\sqrt{n_a(1-n_a)}$$

$$= n_a H\left(1+\kappa\sqrt{\frac{1-n_a}{n_a}}\right) \quad \left(\sim \frac{H}{3}\left(1+\frac{\sqrt{2}}{4}\right) \sim 0.45\,H\right)$$

World Climate Service

If you knew then what we knew then ...

Cost of a Hedge



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$$R_{hf}(p) = R_{\text{clim}} + f_a(p)(F_a(p)H - C(H))$$

World Climate Service

If you knew then what we knew then ...

Season Type: Seasonal

Season: Winter

Location: North America

Variable: Temperature

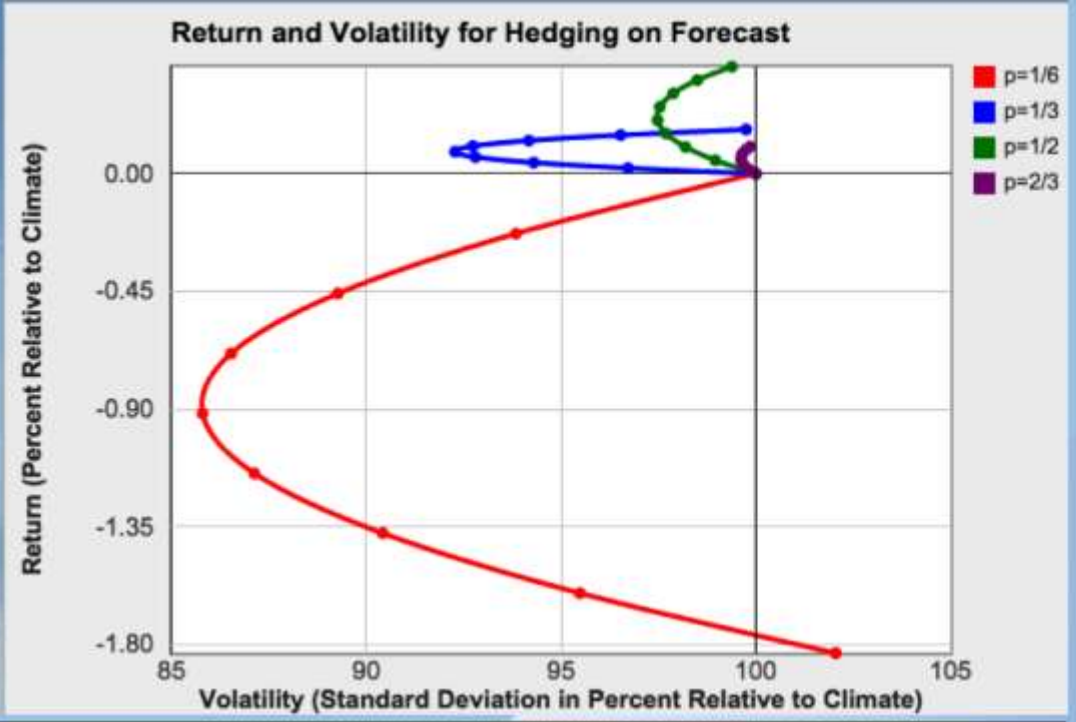
Adverse Tail: Below Normal

Volatility Fraction: 1/4

Favorable Return: $ 100

Adverse Return: $ 67

Units Relative To: (•) Climate ( ) Returns



Season Type: Seasonal

Season: Winter

Location: North America

Variable: Temperature

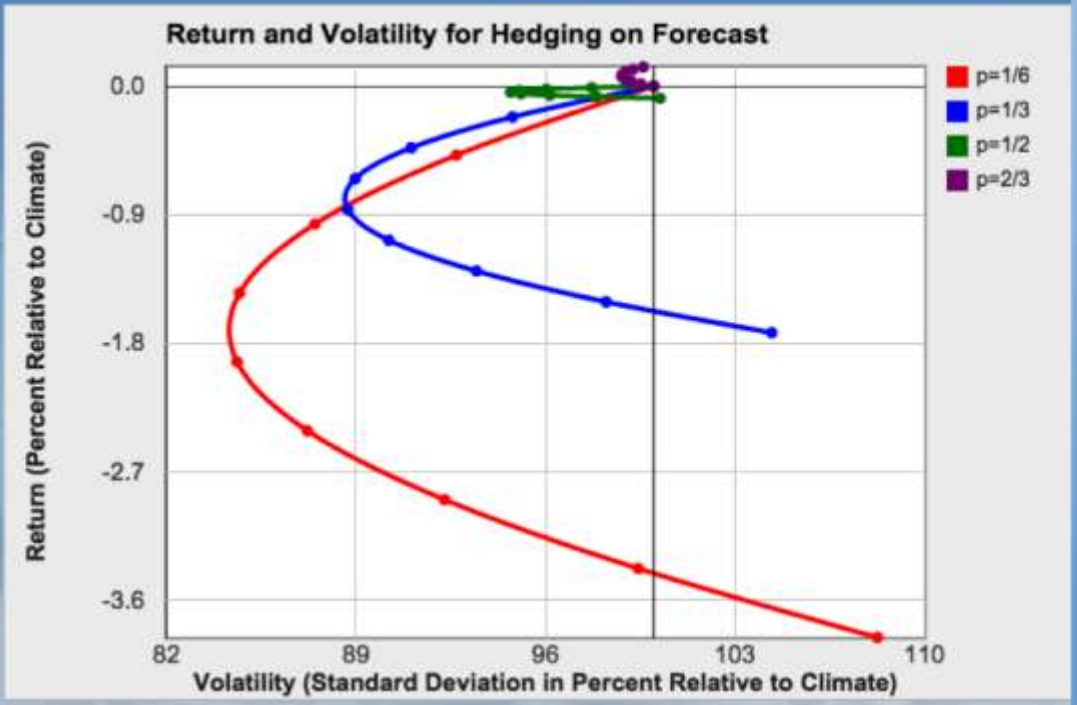
Adverse Tail: Above Normal

Volatility Fraction: 1/2

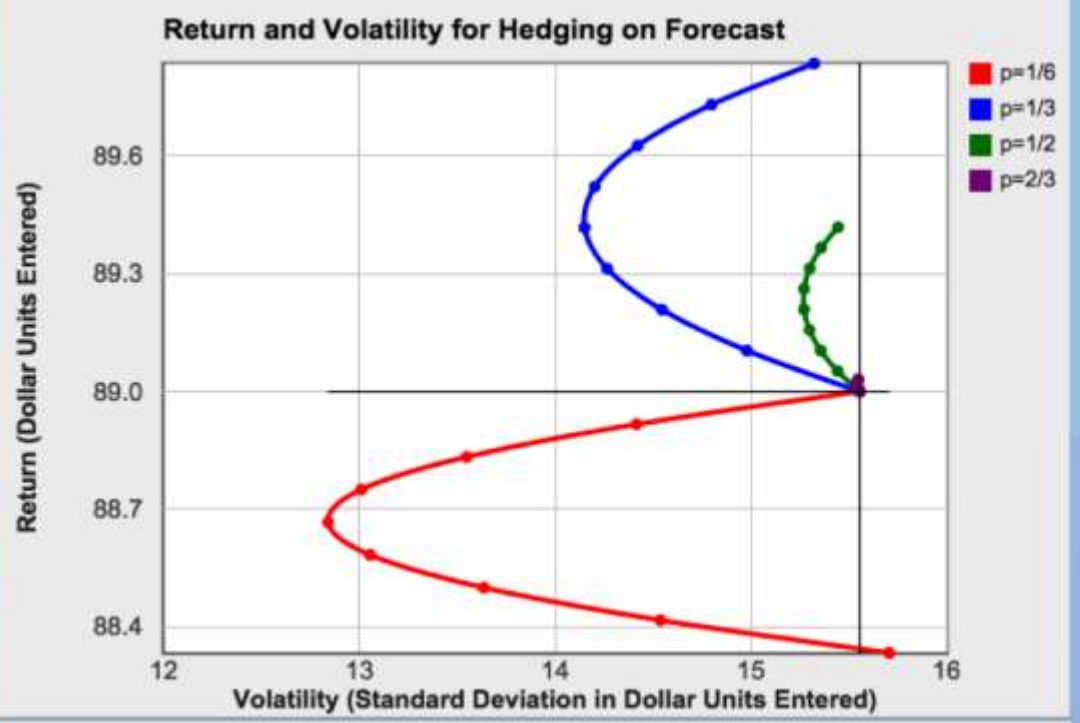
Favorable Return: $ 100

Adverse Return: $ 67

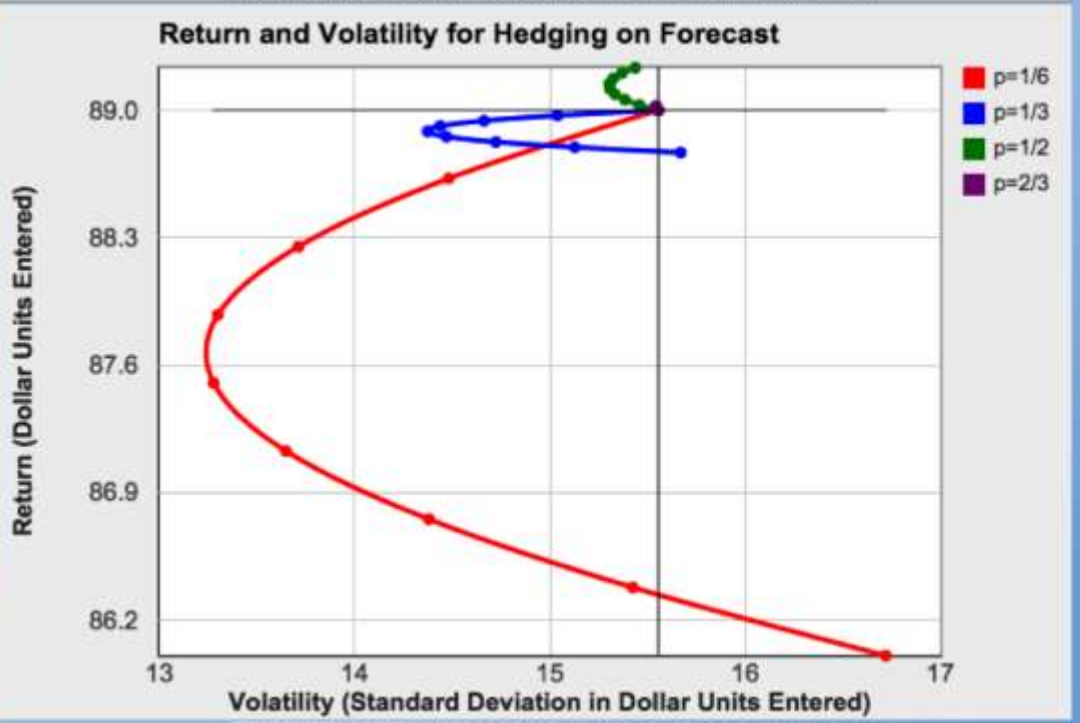
Units Relative To: (•) Climate ( ) Returns



Season Type:	Sub-seasonal
Season:	Summer
Location:	Europe
Variable:	Temperature
Adverse Tail:	Below Normal
Volatility Fraction:	1/4
Favorable Return:	$ 100
Adverse Return:	$ 67
Units Relative To:	○ Climate ◉ Returns



Season Type:	Sub-seasonal
Season:	Summer
Location:	Europe
Variable:	Temperature
Adverse Tail:	Below Normal
Volatility Fraction:	1/2
Favorable Return:	$ 100
Adverse Return:	$ 67
Units Relative To:	○ Climate ◉ Returns



Conclusion

- The expected consequences of mitigating adverse events can be determined if we have reliable, quantitative forecast performance statistics.
- Hedging or mitigating on forecast of adverse conditions is then a viable option with predictable statistical results.
- Sellers of hedges must have forecasts at least as skillful as those of the customers to stay in business.

Conclusion

- The expected consequences of mitigating adverse events can be determined if we have reliable, quantitative forecast performance statistics.
- Hedging or mitigating on forecast of adverse conditions is then a viable option with predictable statistical results.
- Sellers of hedges must have forecasts at least as skillful as those of the customers to stay in business.

Hedging on Forecast Can Be A Very Successful Strategy with Forecasts as Skillful as Those Described Here

Implications for Seasonal and Subseasonal Forecast Systems

- The forecast history is a significant and key component of the forecast system and is essential for:
  - Calibration of the forecasts with re-analyses or observations
  - Establishing rigorous forecast performance statistics
- The forecast history should be an exact replica of the forecasts
  - Same grid and time interval
  - Same ensemble structure – number of members and initialization strategy
- The forecast history should be computed as part of every forecast run over as long a period as possible – say 30 years for seasonal forecasts and 10 years for subseasonal

Implications for NMME

We cannot not now risk making the investment required to offer NMME as a WCS product, because

- **The forecasts are presented on an ftp server —not an operational NCEP server (who ensures they will be there?)**
- **Anomalies rather than the original model fields are presented; we must do our own calibration with our own methods with respect to climatology periods preferred by our clients**
- **The NMME historical data is disorganized—some here, some there— and with considerable confusion about which histories correspond to which models**
- **The subseasonal forecasts offer great commercial opportunity but must meet requirements for S2S forecasts stated on the previous slide.**

Expect the Mean
Hedge the Extreme
Use the Forecast
To Go In Between

Acknowledgments

- This research was supported in part by a NOAA Small Business Innovation Research grant
- The algorithm for the cost of the hedge was provided by Stuart Brown, Swiss Re, London

Reference

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Calibration and combination of dynamical seasonal forecasts to enhance the value of predicted probabilities for managing risk, *Climate Dynamics*, 2013, 40: 3089-3105